

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
19 September 2002 (19.09.2002)

PCT

(10) International Publication Number
WO 02/072355 A1

(51) International Patent Classification⁷: **B41F 33/00**

(21) International Application Number: PCT/US01/47253

(22) International Filing Date: 5 December 2001 (05.12.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/251,699 6 December 2000 (06.12.2000) US

(71) Applicant: **DELAWARE CAPITAL FORMATION, INC.** [US/US]; 1403 Foulk Road, Suite 102, Wilmington, Delaware 19803 (US).

(72) Inventors: **BRYDGES, David**; 160 Missouri Street, San Francisco, CA 94107 (US). **TOBIASON, Erik**; 578 Sky-park Drive, Scotts Valley, CA 95066 (US).

(74) Agents: **POLLOCK, Michael, J. et al.**; Stallman & Pollock LLP, 121 Spear Street, Suite 290, San Francisco, CA 94105 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

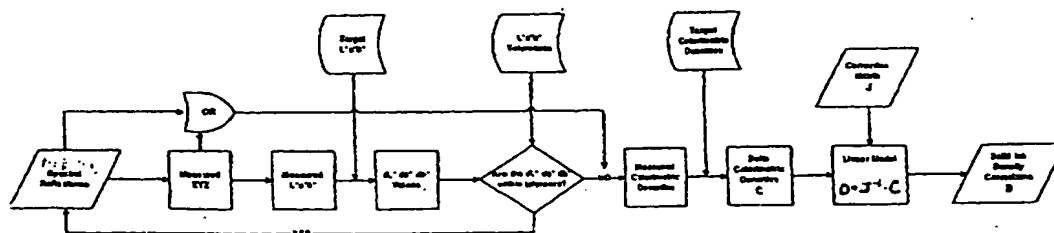
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR CONTROLLING COLOR OF A PRINTING PRESS



(57) Abstract: When a color-difference exceeds an established color tolerance, spectral reflectance values of a test area are converted to colorimetric densities and compared with target colorimetric density values for the corresponding test area from which a colorimetric density difference is established. The colorimetric density difference is utilized to determine an ink correction value.

WO 02/072355 A1

**METHOD AND APPARATUS FOR CONTROLLING COLOR OF A
PRINTING PRESS BASED UPON COLORIMETRIC
DENSITY DIFFERENCES**

5 Inventors: David Brydges; Erik Tobiason

Background of the Invention

1. Field of the Invention

 The present invention relates to color control of printing presses
and, in particular, to utilization of a linear equation to relate colorimetric
10 density difference to solid ink density differences for ink regulation
utilizing an empirically established correction matrix such that color-
difference is minimized.

2. Discussion of the Related Art

15 Instrumental color control applied to the control of a printing
press has as one of its main purposes the task of maintaining a visual
match between an established color target location, which can be in the
form of a customer supplied proof, or printed "Color OK" sheet, etc., and
that same location in subsequently printed sheets such that no visually
20 disturbing color-differences appear throughout the duration of the press
run. If a color-difference exceeds the established color tolerances, then
the appropriate inking adjustments are determined such that the color-
difference is minimized. To determine a visual color match or color-
difference instrumentally, it is a requirement that the instrument provide
25 measurement data either directly or indirectly that are related to the
spectral responses of the human eye. Such instruments include
spectrophotometers and colorimeters.

 In order to minimize the measured color-difference obtained from
measurements using the aforementioned color measuring instrument,
30 an equation describing the relationship between a color-difference and

Equation 1

$$\begin{bmatrix} R \\ C \\ B \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Equation 2

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \bar{r}(\lambda)_i & \dots & \bar{r}(\lambda)_m \\ \bar{g}(\lambda)_i & \dots & \bar{g}(\lambda)_m \\ \bar{b}(\lambda)_i & \dots & \bar{b}(\lambda)_m \end{bmatrix} \begin{bmatrix} P(\lambda)_i \\ \cdot \\ P(\lambda)_m \end{bmatrix}$$

As previously mentioned, a linear matrix equation is used to represent the relationship between solid ink density differences and colorimetric density differences (Equation 3).

Equation 3

$$\mathbf{C} = \mathbf{J} \cdot \mathbf{D}$$

where **C** is a colorimetric density vector containing the red, green and blue filter colorimetric density differences ΔCD_r , ΔCD_g and ΔCD_b receptively, **D** is a solid ink density difference vector containing the cyan, magenta and yellow density differences ΔD_c , ΔD_m and ΔD_y respectively measured through their primary color filter, and **J** is a 3 x 3 "correction" matrix relating the two vectors.

The correction matrix contains the partial derivatives of the dependent variable with respect to the independent variable. The elements of the correction matrix are highly dependant upon several factors that include the printing conditions (ink, paper, press, etc.), area coverage of the primary inks, and the location of the target color in color space. As a result, a correction matrix is required for each test area to overcome the aforementioned problems. Additionally, due to changes in the operating conditions of the press throughout a press run, which can have an influence on the print characteristics, the transformation matrix

determined initially will likely need updating until the operating conditions have stabilized.

The correction matrix presented in Equation 3 relates differences in solid ink density to the corresponding differences in colorimetric density. The elements of the matrix are the partial derivatives of colorimetric density differences with respect to solid ink density differences presented below.

$$\mathbf{J} = \begin{bmatrix} \frac{\partial CD_r}{\partial Dc} & \frac{\partial CD_r}{\partial Dm} & \frac{\partial CD_r}{\partial Dy} \\ \frac{\partial CD_g}{\partial Dc} & \frac{\partial CD_g}{\partial Dm} & \frac{\partial CD_g}{\partial Dy} \\ \frac{\partial CD_b}{\partial Dc} & \frac{\partial CD_b}{\partial Dm} & \frac{\partial CD_b}{\partial Dy} \end{bmatrix}$$

The elements in column one describe the changes in the red, green and blue colorimetric densities of a specific test element for a given cyan solid ink density difference. The remaining columns describe the same relationship for a given density differences in magenta and yellow, respectively. One method of obtaining these elements would be to adjust the cyan, magenta and yellow solid ink density values independently and measure the resulting change in the red, green and blue colorimetric density values. The limitation of this approach is that it would require specific solid ink density changes to be made while the press is printing that may be contradictory to those necessary for control at that point in time thereby reducing the efficiency of the control method. The proposed method, which would overcome this limitation, estimates the elements of the correction matrix using the method of least-squares. The least-square estimates of the elements of the correction matrix are calculated according to Equation 4.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 01/47253

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 6024018	A	15-02-2000	AU 6745198 A GB 2338451 A WO 9843814 A2	22-10-1998 22-12-1999 08-10-1998
US 5068810	A	26-11-1991	DE 59003421 D1 EP 0408507 A1 JP 3056832 A	16-12-1993 16-01-1991 12-03-1991
DE 19617016	A	27-11-1997	DE 19617016 A1	27-11-1997

THIS PAGE BLANK (USPTO)

2/2

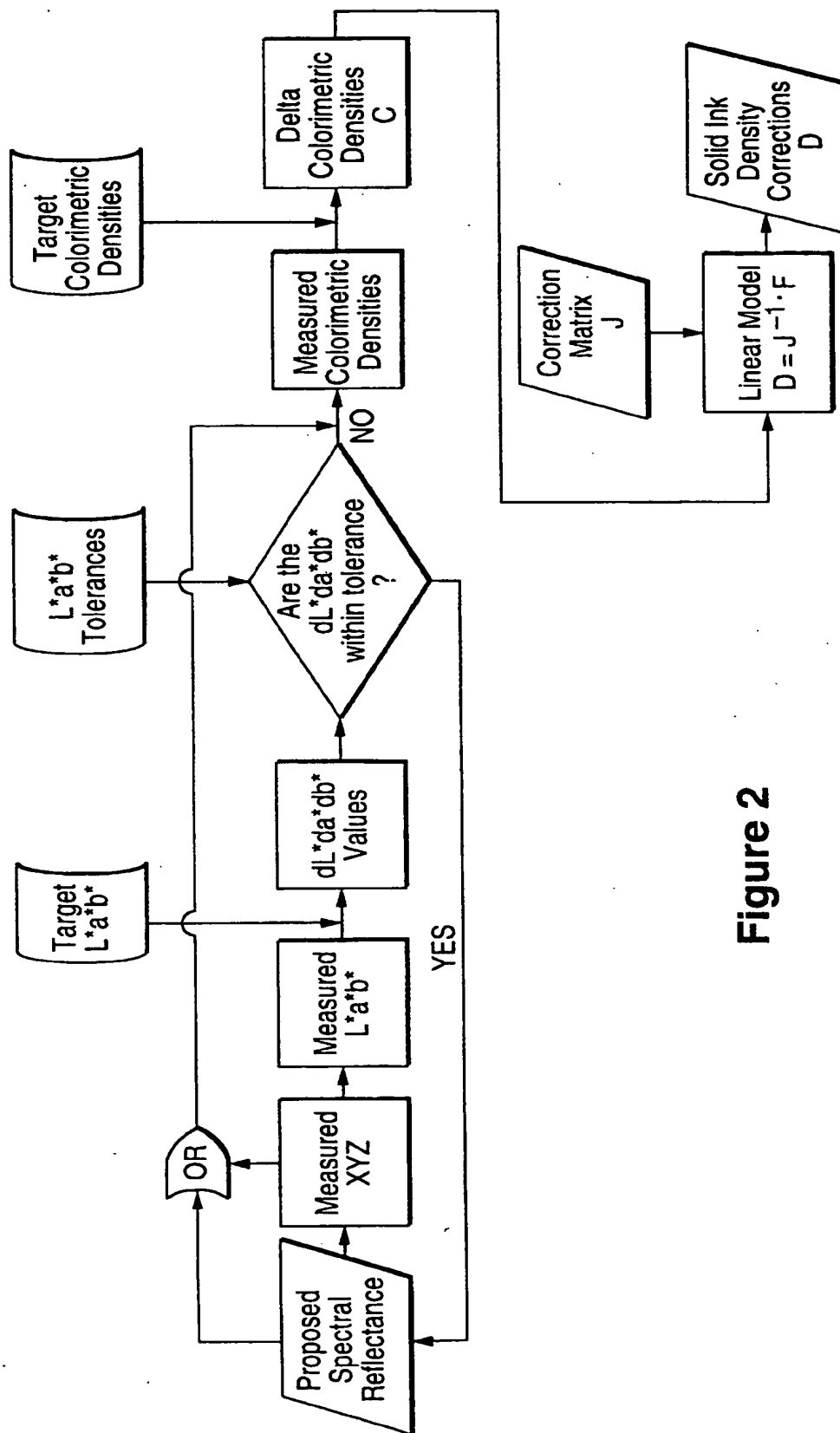


Figure 2

SUBSTITUTE SHEET (RULE 20)

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 01/47253

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B41F33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B41F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 024 018 A (NAGLER MIRIAM ET AL) 15 February 2000 (2000-02-15) abstract figure 10 column 3, line 34 - line 59 column 11, line 5 - column 15, line 9	1,2
X	US 5 068 810 A (OTT HANS) 26 November 1991 (1991-11-26) abstract figures 2-4	1,2
A	DE 196 17 016 A (FUCHS THOMAS ;FUCHS ANNETTE DR ING (DE)) 27 November 1997 (1997-11-27) column 3, line 7 - line 25	1,2

☐ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

G document member of the same patent family

Date of the actual completion of the international search

30 July 2002

Date of mailing of the international search report

14/08/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Windecker, R

What is claimed is:

1. A method of controlling ink feed to a printing press, the method comprising:
 - determining, utilizing a first color space, whether a calculated
 - 5 color-difference is within an established color tolerance; and
 - if the calculated color-difference is determined to exceed the established color tolerance, calculating an ink correction value utilizing a second color space.
- 10 2. A method of controlling ink feed to a printing press, the method comprising:
 - determining whether a color difference exceeds an established color tolerance;
 - if the color difference exceeds established color tolerance,
 - 15 converting spectral reflectance values of a test area used to determine the color difference into colorimetric density values;
 - utilizing the colorimetric density values to establish a colorimetric density difference; and
 - utilizing the colorimetric density difference to calculate an ink
 - 20 correction value.

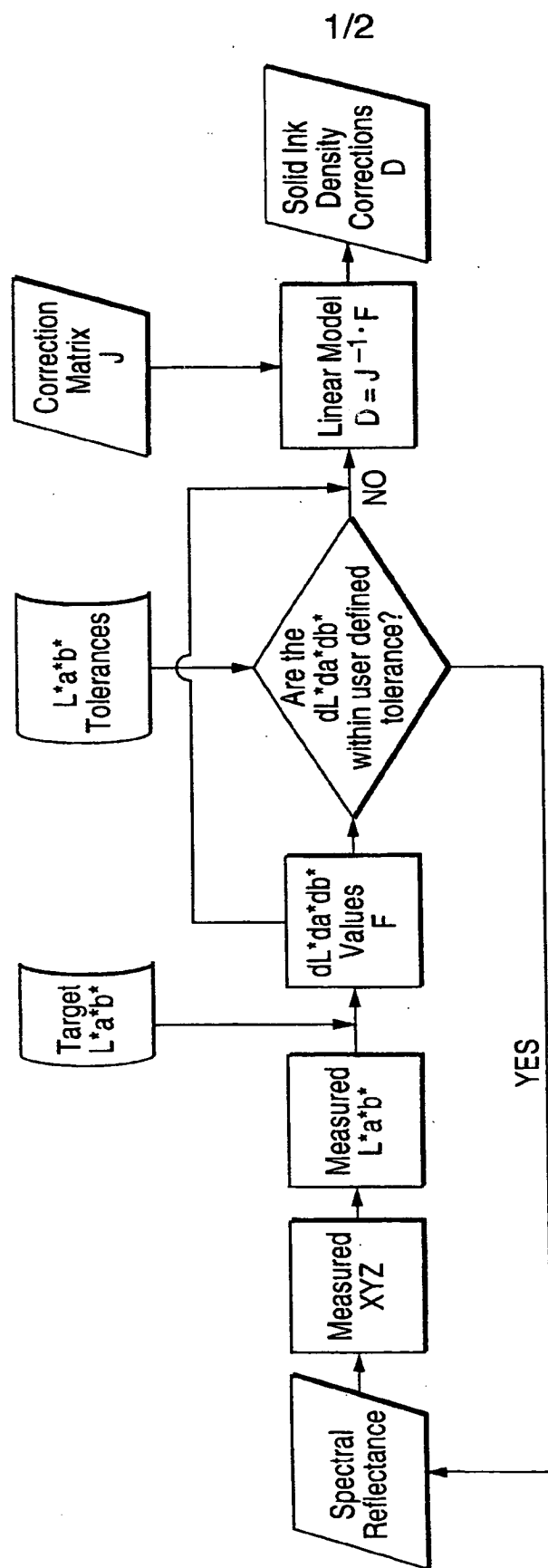


Figure 1

SUBSTITUTE SHEET (RULE 26)

determined initially will likely need updating until the operating conditions have stabilized.

The correction matrix presented in Equation 3 relates differences in solid ink density to the corresponding differences in colorimetric density. The elements of the matrix are the partial derivatives of colorimetric density differences with respect to solid ink density differences presented below.

$$\mathbf{J} = \begin{bmatrix} \frac{\partial CD_r}{\partial Dc} & \frac{\partial CD_r}{\partial Dm} & \frac{\partial CD_r}{\partial Dy} \\ \frac{\partial CD_g}{\partial Dc} & \frac{\partial CD_g}{\partial Dm} & \frac{\partial CD_g}{\partial Dy} \\ \frac{\partial CD_b}{\partial Dc} & \frac{\partial CD_b}{\partial Dm} & \frac{\partial CD_b}{\partial Dy} \end{bmatrix}$$

The elements in column one describe the changes in the red, green and blue colorimetric densities of a specific test element for a given cyan solid ink density difference. The remaining columns describe the same relationship for a given density differences in magenta and yellow, respectively. One method of obtaining these elements would be to adjust the cyan, magenta and yellow solid ink density values independently and measure the resulting change in the red, green and blue colorimetric density values. The limitation of this approach is that it would require specific solid ink density changes to be made while the press is printing that may be contradictory to those necessary for control at that point in time thereby reducing the efficiency of the control method. The proposed method, which would overcome this limitation, estimates the elements of the correction matrix using the method of least-squares. The least-square estimates of the elements of the correction matrix are calculated according to Equation 4.

Equation 4

$$J = (X'X)^{-1} \cdot X'Y$$

where **X** is an $m \times 3$ matrix of values of the dependent variable, **Y** is an $M \times e$ matrix of values of the independent variable, and m is the number of samples used in the estimation. The elements of the correction matrix can be determined from the solid ink density and colorimetric density differences available during the initial make-ready process. In this manner, no additional solid ink density changes are necessary and the estimated elements of the matrix may further account for any secondary effects which may occur when more than one ink is adjusted simultaneously.

To obtain the necessary inking corrections for a given colorimetric density difference, we are interested in the inverse relationship presented in Equation 3. This is obtained by inverting the correction matrix and multiplying the colorimetric density difference by the inverted correction matrix (Equation 5).

Equation 5

$$D = J^{-1} \cdot C$$

The least-squares estimates of the correction matrix elements is determined in the same manner as presented in Equation 4 with the independent variable being colorimetric density differences and the dependent variable being solid ink density differences. Implementation of the calculated solid ink density corrections will minimize the stated color-difference.

The following describes the proposed method for calculating the colorimetric densities of a test swatch for use in determining the solid ink density control values to minimize a color-difference. As previously mentioned, a color control system for the purpose of maintaining color-deviations within visually acceptable tolerances must describe colors in a manner similar to the human eye. To maintain this requirement, and bypass the aforementioned limitation in using CIE recommended uniform color difference parameters, the colorimetric density space is used. Under the Luther-Ives condition, any linear transformation of the color-matching functions will also be a set of color matching functions and will, therefore, be related to the spectral responses of the human eye. Such transformations are described in books on colorimetry, including e.g., "Measuring Color", second edition, by R.W.G. Hunt. The weights used in this work (Equations 1 and 2) are not chosen arbitrarily, but are selected to optimize the relationship between colorimetric density differences and control values.

The reverse transformation equations are used to calculate Red (R), Green (G), and Blue (B) tristimulus values from either X, Y and Z tristimulus values (Equation 1) or from spectral reflectance values (Equation 2) where n is the number of wavelength intervals. The resulting Red, Green and Blue tristimulus values, which are reflectance values, are converted into density values in the standard manner (Density = $-\log(\text{Reflectance})$). Since the density values are tristimulus representations, if two swatches have the same colorimetric densities and are viewed under the same viewing conditions by an observer with color vision not significantly different than the CIE E standard observer, they will look the same.

Equation 1

$$\begin{bmatrix} R \\ C \\ B \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Equation 2

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \bar{r}(\lambda)_i & \dots & \bar{r}(\lambda)_m \\ \bar{g}(\lambda)_i & \dots & \bar{g}(\lambda)_m \\ \bar{b}(\lambda)_i & \dots & \bar{b}(\lambda)_m \end{bmatrix} \begin{bmatrix} P(\lambda)_i \\ \cdot \\ P(\lambda)_m \end{bmatrix}$$

As previously mentioned, a linear matrix equation is used to represent the relationship between solid ink density differences and colorimetric density differences (Equation 3).

Equation 3

$$\mathbf{C} = \mathbf{J} \cdot \mathbf{D}$$

where **C** is a colorimetric density vector containing the red, green and blue filter colorimetric density differences ΔCD_r , ΔCD_g and ΔCD_b receptively, **D** is a solid ink density difference vector containing the cyan, magenta and yellow density differences ΔD_c , ΔD_m and ΔD_y respectively measured through their primary color filter, and **J** is a 3 x 3 "correction" matrix relating the two vectors.

The correction matrix contains the partial derivatives of the dependent variable with respect to the independent variable. The elements of the correction matrix are highly dependant upon several factors that include the printing conditions (ink, paper, press, etc.), area coverage of the primary inks, and the location of the target color in color space. As a result, a correction matrix is required for each test area to overcome the aforementioned problems. Additionally, due to changes in the operating conditions of the press throughout a press run, which can have an influence on the print characteristics, the transformation matrix

light reflecting characteristics of an object over the visible spectrum at some small constant width wavelength interval. The reflectance values are obtained by calculating the spectral reflectance factor, which is a ratio of the amount of light reflected from the sample relative to that of a standard reference material similarly illuminated, wavelength by wavelength across the visible spectrum. Spectrophotometers have the added advantage that the spectral reflectance values can be converted to both colorimetric and densitometric representations according to standard calculations. Throughout this document, when the term density is used outside of the context of a "colorimetric density" or "colorimetric density difference", it is used to refer to densities calculated according to standard practice as documented in, for example, American National Standard for Photography (Sensitometry) - Density Measurements - Spectral Conditions. ANSI/ISO 5/3 - 1984, ANSI PH2.18 - 1985, New York: American National Standards Institute, 1985.

According to the present invention, the spectral reflectance values of a test area are converted to color coordinates in one of the CIE recommended uniform color spaces (CIELAB, CIELUV) which have as their primary advantage the ability to quantify color in approximate visual terms. To obtain coordinates in such a color space, the spectral reflectance values of the test swatch are first converted into X, Y and Z tristimulus values according to standard well-known calculations. The weights used in the calculations include a component related to the spectral responses of the human eye for an average observer and are referred to as the CIE color-matching functions. The X, Y and Z tristimulus values are then used to calculate the color coordinates in a CIE recommended uniform color space (CIELAB or CIELUV).

The uniform color coordinates of the test swatch are compared to those of a corresponding target swatch represented in the same color space to obtain color parameter difference values. The target color

coordinates may be obtained in several ways which include, measurement on a previously printed sheet termed a "Color OK" sheet, manually entered at an operator console or from pre-press data files, which are used to provide downstream operations with a priori

5 information for increased process efficiency. Such a format currently in use is the CIP4 (International Cooperation for Integration of Processes in Pre-Press, Press and Post-Press). Furthermore, the color parameter differences such as ΔL^* , Δa^* , Δb^* and ΔC^* or ΔL^* , ΔU^* and Δv^* can be used to calculate a total color-difference using one of the well-known

10 color-difference equations such as ΔE^*_{ab} , ΔE^*_{uv} , ΔE^*_{94} , etc. To determine whether an inking correction is required to reduce the color-difference, the color parameter differences and total color-difference values are compared to established color tolerances for the target color. The color tolerances for a target color are established prior to printing

15 and may be based on either industry standards or printing plant specific. If it is found that the calculated color-difference is within the established color tolerances, no correction is necessary. If the color-difference is found to exceed the established color tolerances, an inking correction is calculated such that the color-difference is minimized.

20 The main impetus for initially calculating a color-difference based on color space parameters from one of the CIE recommended uniform color spaces is due to their use in commonly used total color-difference equations which describe color-differences in approximate visual terms and their wide acceptance and use in standards activities and at various

25 stages of the color image reproduction process. However, it has been found that the direct transformation between color-differences defined in CIE uniform color space parameters and solid ink density deviations used for press control is less than optimal due to the inherent differences between the two representations. As a result, an alternate

30 representation, colorimetric density, is used for calculating the control values.

one point in time. Dynamic methods of calculating the matrix on-line in real-time during the press run will greatly improve its effectiveness and accuracy.

5

Summary of the Invention

The present invention provides an improved method of color control for printing presses by converting color-differences between a target area and a test area into solid ink density corrections through the use of a color space which is both colorimetric and more nearly related to solid ink density differences than the CIE recommended uniform color spaces previously used. The method maintains the use of CIE recommended uniform color parameters for determining whether or not a color correction is necessary. If a color correction is necessary, then an alternate color representation, colorimetric density, is used to determine the appropriate inking adjustments. The method establishes an increased region around a target color over which an assumption of linearity is valid. This increased linearity provides for a more accurate and robust color control method. In addition, the invention presents a robust method for calculating parameters of the linear model relating colorimetric density differences and control values on-line in real time during the press run.

The features and advantages of the present invention will be more fully understood and appreciated by reference to the following detailed description of the invention which should be considered in conjunction with the drawings.

25

Description of the Drawings

Fig. 1 is a flow chart illustrating a conventional printing press color control method.

Fig. 2 is a flow chart illustrating a printing press color control technique in accordance with the present invention.

30

Detailed Description of the Invention

The present invention utilizes information obtained from
5 measurements on test swatches for color control. Alternatively, the
measurements could be on image areas within the printed product.

The use of test swatches for measuring print quality attributes
are well known in the field and described in the literature; see e.g.,
"Introduction to Color Bars: A User's guide to Color Bar Application",
10 Graphic Communications Association, 1992. Test swatches commonly
found in color bars include solids (100% area coverage), halftone tints
of various area coverage for each of the primary inks (black, cyan,
magenta and yellow) and two and three-color overprints of the primary
chromatic inks (cyan, magenta and yellow). The test swatches are
15 typically arranged in a row across the press, perpendicular to the press
direction, in the form of a color bar. The color bar can be divided into
zones corresponding to the inking zones of the printing press. Control
of the inking in most printing presses is carried out on a zone by zone
basis where each zone corresponds to a width of, for example, 40 mm.
20 Within each zone, an ink key, or servo in an automated ink control
system, is used to adjust the amount of ink flowing into this region of
the press which will in turn influence the color of the swatches located
within the zone. In this manner the inking can be adjusted to produce
the desired colors of the swatches.

25 In order to determine the color of a test swatch, a measurement
instrument for detecting the light reflected from a test swatch is
necessary. The measurement instrument is preferably a
spectrophotometer. The preferred and well-known method for
collecting and analyzing light with a spectrophotometer is the use of a
30 spectral grating and an array of sensors with computer analysis. The
output is a set of spectral reflectance values that describe the relative

coordinates may be obtained in several ways which include, measurement on a previously printed sheet termed a "Color OK" sheet, manually entered at an operator console or from pre-press data files, which are used to provide downstream operations with a priori

5 information for increased process efficiency. Such a format currently in use is the CIP4 (International Cooperation for Integration of Processes in Pre-Press, Press and Post-Press). Furthermore, the color parameter differences such as ΔL^* , Δa^* , Δb^* and ΔC^* or ΔL^* , ΔU^* and Δv^* can be used to calculate a total color-difference using one of the well-known

10 color-difference equations such as ΔE^*_{ab} , ΔE^*_{uv} , ΔE^*_{94} , etc. To determine whether an inking correction is required to reduce the color-difference, the color parameter differences and total color-difference values are compared to established color tolerances for the target color. The color tolerances for a target color are established prior to printing

15 and may be based on either industry standards or printing plant specific. If it is found that the calculated color-difference is within the established color tolerances, no correction is necessary. If the color-difference is found to exceed the established color tolerances, an inking correction is calculated such that the color-difference is minimized.

20 The main impetus for initially calculating a color-difference based on color space parameters from one of the CIE recommended uniform color spaces is due to their use in commonly used total color-difference equations which describe color-differences in approximate visual terms and their wide acceptance and use in standards activities and at various

25 stages of the color image reproduction process. However, it has been found that the direct transformation between color-differences defined in CIE uniform color space parameters and solid ink density deviations used for press control is less than optimal due to the inherent differences between the two representations. As a result, an alternate

30 representation, colorimetric density, is used for calculating the control values.

The following describes the proposed method for calculating the colorimetric densities of a test swatch for use in determining the solid ink density control values to minimize a color-difference. As previously mentioned, a color control system for the purpose of maintaining color-deviations within visually acceptable tolerances must describe colors in a manner similar to the human eye. To maintain this requirement, and bypass the aforementioned limitation in using CIE recommended uniform color difference parameters, the colorimetric density space is used. Under the Luther-Ives condition, any linear transformation of the color-matching functions will also be a set of color matching functions and will, therefore, be related to the spectral responses of the human eye. Such transformations are described in books on colorimetry, including e.g., "Measuring Color", second edition, by R.W.G. Hunt. The weights used in this work (Equations 1 and 2) are not chosen arbitrarily, but are selected to optimize the relationship between colorimetric density differences and control values.

The reverse transformation equations are used to calculate Red (R), Green (G), and Blue (B) tristimulus values from either X, Y and Z tristimulus values (Equation 1) or from spectral reflectance values (Equation 2) where n is the number of wavelength intervals. The resulting Red, Green and Blue tristimulus values, which are reflectance values, are converted into density values in the standard manner (Density = $-\log(\text{Reflectance})$). Since the density values are tristimulus representations, if two swatches have the same colorimetric densities and are viewed under the same viewing conditions by an observer with color vision not significantly different than the CIE E standard observer, they will look the same.

METHOD AND APPARATUS FOR CONTROLLING COLOR OF A PRINTING PRESS

5

Inventors: David Brydges; Erik Tobiason

Background of the Invention

1. Field of the Invention

The present invention relates to color control of printing presses and, in particular, to utilization of a linear equation to relate colorimetric
10 density difference to solid ink density differences for ink regulation utilizing an empirically established correction matrix such that color-difference is minimized.

2. Discussion of the Related Art

15 Instrumental color control applied to the control of a printing press has as one of its main purposes the task of maintaining a visual match between an established color target location, which can be in the form of a customer supplied proof, or printed "Color OK" sheet, etc., and that same location in subsequently printed sheets such that no visually
20 disturbing color-differences appear throughout the duration of the press run. If a color-difference exceeds the established color tolerances, then the appropriate inking adjustments are determined such that the color-difference is minimized. To determine a visual color match or color-difference instrumentally, it is a requirement that the instrument provide
25 measurement data either directly or indirectly that are related to the spectral responses of the human eye. Such instruments include spectrophotometers and colorimeters.

In order to minimize the measured color-difference obtained from measurements using the aforementioned color measuring instrument,
30 an equation describing the relationship between a color-difference and

the appropriate control values is required. In printing, the main press control influencing the visual impression of the printed image is the inking system, which modulates the flow of ink into the press. An adjustment to the inking system in order to minimize a color difference
5 is usually described as a density difference or an ink layer thickness difference.

For control purposes, it is highly desirable to choose a response variable that is linearly related to changes in the control variable over as large a region as possible. Although, multi-color halftone image
10 reproduction is in general a non-linear process, under certain conditions it is possible to use linear equations to model the process by restricting the range of the transformation to a sub-region of the color gamut. Within each sub-region, which has the target color value as its origin, a set of "localized" equations can be used. The region over which the
15 localized transformations will be linear is dependent upon the target color location and the color space used to represent the color differences used in the transformation.

Methods for performing such a procedure utilizing CIE recommended uniform color-difference parameters as the response
20 variables are described in U.S. Pat. No. 4,975,862, U.S. Pat. No. 5,182,721 and U.S. Pat. No. 6,041,708.

Several aspects of the aforementioned U.S. patents can be improved upon for use in a color control system. While differences between colors described in CIE recommended uniform color space
25 parameters, and their associated total color-difference equations, are very useful for describing color-differences, they are not the ideal color-difference descriptors from which to calculate inking control values based upon a linear model. Additionally, off-line methods of calculating the parameters of the matrix relating solid ink density differences to
30 color-differences are not accurate enough for use in a commercial color control system. Such methods only represent the state of the system at

the appropriate control values is required. In printing, the main press control influencing the visual impression of the printed image is the inking system, which modulates the flow of ink into the press. An adjustment to the inking system in order to minimize a color difference
5 is usually described as a density difference or an ink layer thickness difference.

For control purposes, it is highly desirable to choose a response variable that is linearly related to changes in the control variable over as large a region as possible. Although, multi-color halftone image
10 reproduction is in general a non-linear process, under certain conditions it is possible to use linear equations to model the process by restricting the range of the transformation to a sub-region of the color gamut. Within each sub-region, which has the target color value as its origin, a set of "localized" equations can be used. The region over which the
15 localized transformations will be linear is dependent upon the target color location and the color space used to represent the color differences used in the transformation.

Methods for performing such a procedure utilizing CIE recommended uniform color-difference parameters as the response
20 variables are described in U.S. Pat. No. 4,975,862, U.S. Pat. No. 5,182,721 and U.S. Pat. No. 6,041,708.

Several aspects of the aforementioned U.S. patents can be improved upon for use in a color control system. While differences between colors described in CIE recommended uniform color space
25 parameters, and their associated total color-difference equations, are very useful for describing color-differences, they are not the ideal color-difference descriptors from which to calculate inking control values based upon a linear model. Additionally, off-line methods of calculating the parameters of the matrix relating solid ink density differences to
30 color-differences are not accurate enough for use in a commercial color control system. Such methods only represent the state of the system at

one point in time. Dynamic methods of calculating the matrix on-line in real-time during the press run will greatly improve its effectiveness and accuracy.

5

Summary of the Invention

The present invention provides an improved method of color control for printing presses by converting color-differences between a target area and a test area into solid ink density corrections through the use of a color space which is both colorimetric and more nearly related to solid ink density differences than the CIE recommended uniform color spaces previously used. The method maintains the use of CIE recommended uniform color parameters for determining whether or not a color correction is necessary. If a color correction is necessary, then an alternate color representation, colorimetric density, is used to determine the appropriate inking adjustments. The method establishes an increased region around a target color over which an assumption of linearity is valid. This increased linearity provides for a more accurate and robust color control method. In addition, the invention presents a robust method for calculating parameters of the linear model relating colorimetric density differences and control values on-line in real time during the press run.

The features and advantages of the present invention will be more fully understood and appreciated by reference to the following detailed description of the invention which should be considered in conjunction with the drawings.

25

Description of the Drawings

Fig. 1 is a flow chart illustrating a conventional printing press color control method.

Fig. 2 is a flow chart illustrating a printing press color control technique in accordance with the present invention.

30

Detailed Description of the Invention

The present invention utilizes information obtained from
5 measurements on test swatches for color control. Alternatively, the
measurements could be on image areas within the printed product.

The use of test swatches for measuring print quality attributes
are well known in the field and described in the literature; see e.g.,
"Introduction to Color Bars: A User's guide to Color Bar Application",
10 Graphic Communications Association, 1992. Test swatches commonly
found in color bars include solids (100% area coverage), halftone tints
of various area coverage for each of the primary inks (black, cyan,
magenta and yellow) and two and three-color overprints of the primary
chromatic inks (cyan, magenta and yellow). The test swatches are
15 typically arranged in a row across the press, perpendicular to the press
direction, in the form of a color bar. The color bar can be divided into
zones corresponding to the inking zones of the printing press. Control
of the inking in most printing presses is carried out on a zone by zone
basis where each zone corresponds to a width of, for example, 40 mm.
20 Within each zone, an ink key, or servo in an automated ink control
system, is used to adjust the amount of ink flowing into this region of
the press which will in turn influence the color of the swatches located
within the zone. In this manner the inking can be adjusted to produce
the desired colors of the swatches.

25 In order to determine the color of a test swatch, a measurement
instrument for detecting the light reflected from a test swatch is
necessary. The measurement instrument is preferably a
spectrophotometer. The preferred and well-known method for
collecting and analyzing light with a spectrophotometer is the use of a
30 spectral grating and an array of sensors with computer analysis. The
output is a set of spectral reflectance values that describe the relative

light reflecting characteristics of an object over the visible spectrum at some small constant width wavelength interval. The reflectance values are obtained by calculating the spectral reflectance factor, which is a ratio of the amount of light reflected from the sample relative to that of a standard reference material similarly illuminated, wavelength by wavelength across the visible spectrum. Spectrophotometers have the added advantage that the spectral reflectance values can be converted to both colorimetric and densitometric representations according to standard calculations. Throughout this document, when the term density is used outside of the context of a "colorimetric density" or "colorimetric density difference", it is used to refer to densities calculated according to standard practice as documented in, for example, American National Standard for Photography (Sensitometry) - Density Measurements - Spectral Conditions. ANSI/ISO 5/3 - 1984, ANSI PH2.18 - 1985, New York: American National Standards Institute, 1985.

According to the present invention, the spectral reflectance values of a test area are converted to color coordinates in one of the CIE recommended uniform color spaces (CIELAB, CIELUV) which have as their primary advantage the ability to quantify color in approximate visual terms. To obtain coordinates in such a color space, the spectral reflectance values of the test swatch are first converted into X, Y and Z tristimulus values according to standard well-known calculations. The weights used in the calculations include a component related to the spectral responses of the human eye for an average observer and are referred to as the CIE color-matching functions. The X, Y and Z tristimulus values are then used to calculate the color coordinates in a CIE recommended uniform color space (CIELAB or CIELUV).

The uniform color coordinates of the test swatch are compared to those of a corresponding target swatch represented in the same color space to obtain color parameter difference values. The target color

Equation 4

$$J = (X'X)^{-1} \cdot X'Y$$

where **X** is an m x 3 matrix of values of the dependent variable, **Y** is an
M x e matrix of values of the independent variable, and m is the number
5 of samples used in the estimation. The elements of the correction
matrix can be determined from the solid ink density and colorimetric
density differences available during the initial make-ready process. In
this manner, no additional solid ink density changes are necessary and
the estimated elements of the matrix may further account for any
10 secondary effects which may occur when more than one ink is adjusted
simultaneously.

To obtain the necessary inking corrections for a given colorimetric
density difference, we are interested in the inverse relationship
presented in Equation 3. This is obtained by inverting the correction
15 matrix and multiplying the colorimetric density difference by the inverted
correction matrix (Equation 5).

Equation 5

$$D = J^{-1} \cdot C$$

20 The least-squares estimates of the correction matrix elements is
determined in the same manner as presented in Equation 4 with the
independent variable being colorimetric density differences and the
dependent variable being solid ink density differences. Implementation
of the calculated solid ink density corrections will minimize the stated
25 color-difference.

What is claimed is:

1. A method of controlling ink feed to a printing press, the method comprising:
 - determining, utilizing a first color space, whether a calculated
 - 5 color-difference is within an established color tolerance; and
 - if the calculated color-difference is determined to exceed the established color tolerance, calculating an ink correction value utilizing a second color space.
- 10 2. A method of controlling ink feed to a printing press, the method comprising:
 - determining whether a color difference exceeds an established color tolerance;
 - if the color difference exceeds established color tolerance,
 - 15 converting spectral reflectance values of a test area used to determine the color difference into colorimetric density values;
 - utilizing the colorimetric density values to establish a colorimetric density difference; and
 - utilizing the colorimetric density difference to calculate an ink
 - 20 correction value.

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
19 September 2002 (19.09.2002)

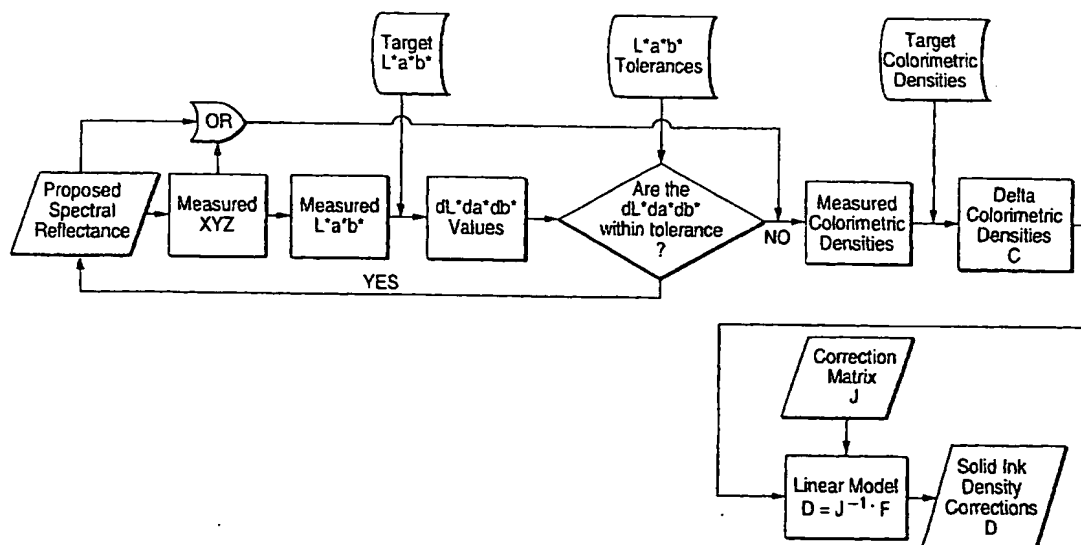
PCT

(10) International Publication Number
WO 02/072355 A1

- (51) International Patent Classification⁷: **B41F 33/00**
- (21) International Application Number: **PCT/US01/47253**
- (22) International Filing Date: 5 December 2001 (05.12.2001)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
60/251,699 6 December 2000 (06.12.2000) US
- (71) Applicant: **DELAWARE CAPITAL FORMATION, INC.** [US/US]; 1403 Foulk Road, Suite 102, Wilmington, Delaware 19803 (US).
- (72) Inventors: **BRYDGES, David**; 160 Missouri Street, San Francisco, CA 94107 (US). **TOBIASON, Erik**; 578 Sky-park Drive, Scotts Valley, CA 95066 (US).
- (74) Agents: **POLLOCK, Michael, J. et al.**; Stallman & Pollock LLP, 121 Spear Street, Suite 290, San Francisco, CA 94105 (US).
- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:
— with international search report
- (48) Date of publication of this corrected version:
1 May 2003
- (15) Information about Correction:
see PCT Gazette No. 18/2003 of 1 May 2003, Section II

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR CONTROLLING COLOR OF A PRINTING PRESS



(57) Abstract: When a color-difference exceeds an established color tolerance, spectral reflectance values of a test area are converted to colorimetric densities and compared with target colorimetric density values for the corresponding test area from which a colorimetric density difference is established. The colorimetric density difference is utilized to determine an ink correction value.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

Information on patent family members

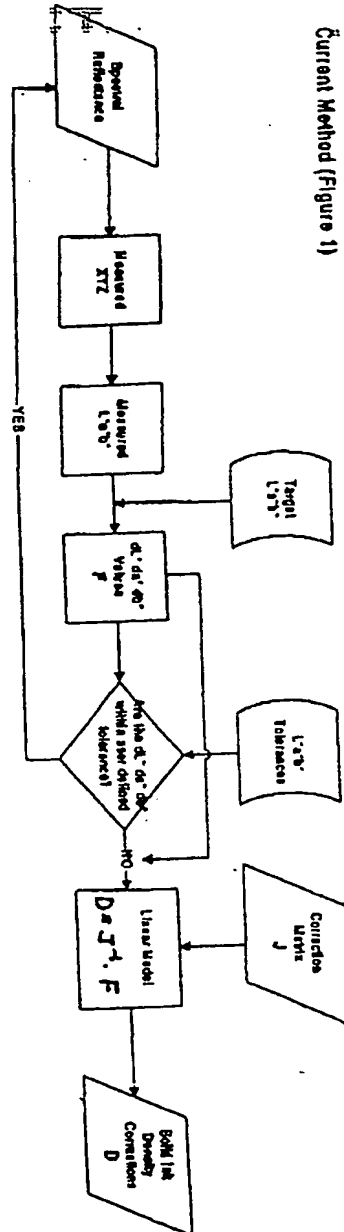
In: International Application No

PCT/US 01/47253

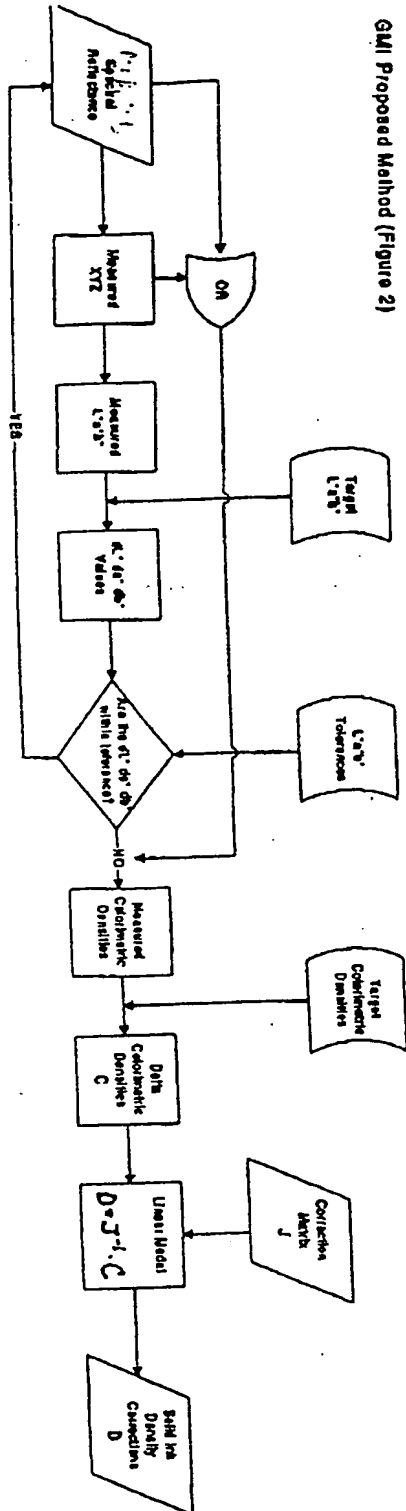
Patent document cited in search report		Publication date		Patent family member(s)		Publication date
US 6024018	A	15-02-2000	AU	6745198 A		22-10-1998
			GB	2338451 A		22-12-1999
			WO	9843814 A2		08-10-1998
US 5068810	A	26-11-1991	DE	59003421 D1		16-12-1993
			EP	0408507 A1		16-01-1991
			JP	3056832 A		12-03-1991
DE 19617016	A	27-11-1997	DE	19617016 A1		27-11-1997

THIS PAGE BLANK (USPTO)

Current Method (Figure 1)



GMI Proposed Method (Figure 2)



INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 01/47253

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B41F33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B41F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 024 018 A (NAGLER MIRIAM ET AL) 15 February 2000 (2000-02-15) abstract figure 10 column 3, line 34 - line 59 column 11, line 5 - column 15, line 9	1,2
X	US 5 068 810 A (OTT HANS) 26 November 1991 (1991-11-26) abstract figures 2-4	1,2
A	DE 196 17 016 A (FUCHS THOMAS ;FUCHS ANNETTE DR ING (DE)) 27 November 1997 (1997-11-27) column 3, line 7 - line 25	1,2



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

Date of the actual completion of the international search

30 July 2002

Date of mailing of the international search report

14/08/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+31-70) 340-3016

Authorized officer

Windecker, R

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☒ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO)